RAW MATERIALS FOR ALUMINUM PRODUCTION

BY D. D. BLUE

* * * * * * * * * **Information Circular 7675**

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
J. J. Forbes, Director

Work on manuscript completed December 1953. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7675."

March 1954

RAW MATERIALS FOR ALUMINUM PRODUCTION

by

D. D. Blue[1]

CONTENTS

	Page
Summary	1
Introduction	1
Acknowledgments	2
Alumina extraction process	2
Bauxite	3
Other materials for alumina production	5
Reduction process	6
Alumina	6
Power	6
Carbon	8
Electrolyte of flux	9
Labor	11

TABLES

1. Chemical specifications for bauxite 3
2. Raw material requirements per ton of alumina 4
3. Raw material requirements per ton of virgin aluminum . 7

---

[1] Assistant chief, Light Metals Branch, Minerals Division.

Information Circular 7675

Original from THE OHIO STATE UNIVERSITY

SUMMARY

To insure domestic production of aluminum for essential civilian and defense uses, the Government, under authority of the Defense Production Act of 1950, programed and promoted an aluminum-expansion program that will more than double the primary production capacity that existed in 1949. In view of this vastly increased production, the raw materials, with respect to both quantity and sources, are reviewed. The raw-material consumption pattern, the requirements during an expansion period when excess quantities of materials for starting up new facilities are consumed, and the probable requirements for production of 1.7 million tons per year of primary aluminum are discussed. The raw materials that presented the most difficult supply problems were bauxite, electrical power, and fluoride salts, and the supply pattern for these materials probably will undergo changes. A major part of the electrical energy for the increased capacity was to come from thermal generation, Jamaica was to become a major source of bauxite, and synthetic fluoride salts were replacing natural cryolite in increasing quantities. Other raw-material requirements discussed are: Soda ash; lime, and limestone; starch; filter cloth; fuel; alumina; the carbonaceous materials, green and calcined petroleum coke, high- and low-temperature pitch and coke or anthracite; cryolite; aluminum fluoride; the materials going into production of synthetic fluorides, acid-grade fluorspar, and sulfuric acid; and labor.

INTRODUCTION

The raw materials for the aluminum industry that have received the most publicity are bauxite, the ore that supplies elemental aluminum, and electrical energy, the means by which aluminum oxide is reduced to metal. A number of other important materials are, however, required in large quantities in the production of primary aluminum metal.

The consumption of aluminum is increasing rapidly, and during the decade from 1939 to 1949, years most nearly comparable from the standpoint of economic and political conditions, the calculated quantity of aluminum consumed by United States industry, excluding plant scrap and stocks held at fabricating plants, increased fivefold, from 234,000 tons to 1,159,000. The use of aluminum in materials of defense and attack is well known, and the trend toward increasing proportions of light-weight airborne and highly mobile ordnance equipment will continue in future to accentuate the demand for wartime aluminum. To insure domestic production of aluminum for essential civilian and defense uses, the Government, under authority of the Defense Production Act of 1950, programed and promoted an expansion program that will more than double the production capacity that existed in 1949. When the program, as planned at the end of 1952, is completed, the estimated annual capacity of the United States primary aluminum producers will exceed 1.7 million tons.

In view of this vastly increased production capacity, it is interesting to review the raw materials, both with respect to quantity and sources, required for this production program. The requirements during an expansion period are not limited to materials consumed in the production process, as additional quantities of these same materials are necessary to initiate production in the new facilities, in other words, to fill the "pipeline."

The materials discussed in this paper are limited to those that are consumed in the production process. The vast amounts of steel and other structural material, the complex chemical equipment, the electrical transmission systems, rectifiers, etc., also represent a draft on our resources but are in many respects similar to those of other chemical and/or electrometallurgical plants. The materials are discussed in the order in which they are required in the production cycle.

ACKNOWLEDGMENTS

The material presented in this paper is largely an outgrowth of a study made in 1951 of the raw materials required for a large-scale expansion of the United States Aluminum Industry. The cooperation of the three established aluminum producers - Aluminum Company of America, Reynolds Metals Co., and Kaiser Aluminum & Chemical Co. - and one prospective producer, Harvey Machine Co., which supplied statistical data on past and projected requirements, is hereby acknowledged.

ALUMINA-EXTRACTION PROCESSES

Three commercial alumina-extraction processes were used in the United States in 1952, and there were differences in raw-material requirements for each type of domestic plant. Until World War II, alumina was obtained by the American Bayer process developed to extract alumina from gibbsitic bauxite (gibbsite is $Al_2O_3.3H_2O$) by a cuastic soda solution. In this process, chemically combined silica in the ore unites with alumina and soda to form an insoluble, zeolitic-type compound that is discarded with resultant decrease in alumina recovery and loss of valuable soda. During World War II when shipments of bauxite from South America were curtailed by action of enemy submarines and an increased consumption of domestic bauxite with a relatively high silica content was necessary, a new process known as the combination process, so named because it was a combination of the Bayer process and a lime-soda sinter process, came into commercial use. The sintering step was also called the red-mud process and was employed to treat residues from the Bayer leach for recovery of additional alumina and soda. In this process limestone is sintered with leach residues to form an insoluble dicalcium silicate, and soda and alumina are leached out and returned to the Bayer circuit. Late in 1952 the United States began using bauxite from Jamaica. This ore had a high iron content and contained boehmite ($Al_2O_3.H_2O$), which is less soluble than gibbsite in the soda extraction. To treat this ore a third process, called the modified Bayer process, was inaugurated in which higher extraction temperatures and a modified technique for separation of the pregnant liquor from the residue is used.

Original from THE OHIO STATE UNIVERSITY

Bauxite

Aluminum is the most abundant metal element in the earth's crust, but up to the present time virtually all of the metal, which we see in so many common applications today, has been produced from bauxite. The term "bauxite" has been applied to the richest naturally occurring materials, which consist mainly of hydrated aluminum oxides. Most of the aluminum found in the earth's crust occurs in chemical combination with silica, as in clays and anhydrous aluminous rocks. However, recovery of alumina from bauxite is less complex and less expensive than from the aluminum silicate materials. Bauxites are deposited in various parts of the world and exhibit greatly varying chemical compositions and physical properties. Unfortunately, the United States, the world's largest consumer of bauxite, has in terms of requirements, only small reserves of this ore and thus must rely to a large extent on imported material. In addition, the domestic reserves are generally of a lower grade than those mined in foreign countries and virtually all of the domestic ore is deposited in two counties in Arkansas.

All bauxite consumed by the United States aluminum industry was processed to extract alumina. For rough calculations of bauxite requirements, a figure of 4 long tons of dried bauxite ore per short ton of metal produced has long been used. It is obvious that bauxite requirements will depend on the type and grade of ore consumed and on the extractive process employed. Consumption of bauxite for metal production in 1951, when both South American and Arkansas bauxite was used, was slightly below the rough figure, averaging 3.74 long tons of dried bauxite for each short ton of metal production. A little over 60 percent of the bauxite supply in 1951 was foreign ore.

From the standpoint of highest alumina recovery coupled with the least complicated extraction technique, bauxite low in silica and with the alumina present as the trihydrate is desirable. The South American bauxite from Surinam and British Guiana is of this type, as is the high-grade domestic ore. Chemical specifications for three types of bauxite for Government-owned stockpiles are shown in table 1. Bauxite requirements based on these minimum specifications of trihydrate ore would be about 2 long dry tons of ore per short ton of alumina. Production statistics show that higher grade ores were used, and in 1951 requirements of Surinam ore were 1.8 long tons of ore per ton of alumina or 3.4 long tons of bauxite per short ton of aluminum.

TABLE 1. - Chemical specifications for bauxite

	Strategic stockpile specifications 1952		Government stockpile World War II
	Trihydrate	Mixed mono. and trihydrate	Arkansas ore
Al_2O_3................	55.0 min.	47.0 min.	50 min.
SiO_2................	5.0 max.	4.0 max.	12 max.
Alkalis (as oxides)..	1.0 max.	1.0 max.	
Ferrous iron (as FeO)	3.0 max.	3.0 max.	6.0 max.
Phosphorus (as P_2O_5).	1.0 max.	1.0 max.	1.0 max.
Manganese, chromium and vanadium (as MnO_2, Cr_2O_3, V_2O_5).	2.0 max.	2.0 max.	2.0 max.
Loss on ignition	50% of Al_2O_3	40% of Al_2O_3	50% of Al_2O_3

All domestic bauxite used for alumina production at the end of 1952 was treated in combination process plants. Ores of varying silica content were processed, and the output or capacity of a combination plant was a function of the silica content of the bauxite. In practice bauxite containing as high as 20 to 25 percent SiO_2 was mined and blended with ore of a lower silica content to give a feed material of the desired composition. It is obvious that greater quantities of bauxite would be required per ton of alumina because of the lower alumina content of high-silica ore.

Very little information is available on treatment of Jamaican bauxite. Calculations based on the stockpile specifications for mixed mono- and trihydrate ore indicate that requirements for the modified Bayer plants are higher than for the combination plants. However, as in the case of trihydrate specifications, these are minimum specifications and companies mining bauxite in Jamaica have reported that much of the ore is of a higher grade, containing more Al_2O_3 and less SiO_2. Requirements will thus be lower than those shown by calculated recoveries.

Bauxite is consumed for other purposes than in production of aluminum, as in the synthetic corundum abrasives, aluminum chemicals, and high-alumina refractories. Alumina extracted from bauxite is also used for purposes other than for reduction to metal. From 1949-51, 87 percent of all bauxite consumed was for production of alumina, and 90 percent of this alumina was reduced to aluminum. Additional small quantities of alumina were used in the production of electrolytes consumed in the reduction process. Over 80 percent of the United States bauxite consumption went into metal production.

The bauxite required for aluminum increased 50 percent from 1949 to 1951, and, assuming capacity aluminum production of 1.7 million tons in 1954 or 1955, bauxite requirements will be over three times those of 1949, totaling 7 million long tons. The capacity of combination process facilities has been doubled, and the consumption of Arkansas ore will increase. Production in Surinam and British Guiana has increased, but the major portion of the additional ore for production of aluminum will come from Jamaica, and it was estimated that within the next 5 years ore from the Caribbean area will almost equal in quantity that from South America.

TABLE 2. - Raw material requirements[1] per ton of alumina

Bauxite	long dry tons	1.8
Soda Ash	lbs.	280
Lime	do .	175
Starch	do .	2.4
Fuel (natural gas)	M.c.f.	12.4
Filter Cloth	yds.	.61
Labor	man-hours	2.7

[1] Based on industrial average in 1951 and requirement forecasts for 1952.

Other Materials for Alumina Production

Other materials consumed in the production of alumina are soda ash, lime and limestone, starch, filter cloth, fuel, and, of course, water and labor.

The soda ash used in alumina production is continuously recycled, and the consumption represents makeup to replace soda lost in process, largely in leach residues. In the Bayer processes soda is discarded as an insoluble sodium aluminum silicate, and in the combination process soda is discarded with the insoluble dicalcium silicate, which, although carrying lower percentage of soda than the Bayer residue, is of considerably greater bulk per unit of alumina recovered. In any of the processes, soda ash consumption is a function of silica content, and, although this consumption is lower per unit of contained silica for the combination process, the requirements per unit of alumina may be as great. The use of Jamaican ore, as compared to trihydrate ore with the same silica-alumina ratio, will probably require slightly more soda ash because of the larger quantities of residue discarded in processing this material.

Soda ash losses averaged about 280 pounds per ton of alumina production equivalent to 530 pounds per ton of aluminum. Soda is also consumed in the production of synthtic cryolite, and small amounts may periodically be added to the electrolyte of the reduction cells. Soda ash requirements for filling the leach circuit in new alumina plants are small in relation to process consumption and amount to about 50 pounds per annual ton of new alumina capacity. About 75,000 tons of soda ash will be required for starting up new plants during 1951-54, compared to a process consumption of 450,000 tons per year in 1955. These requirements were less than 5 percent of total United States soda-ash consumption, and no difficulties were foreseen in obtaining the material from domestic producers.

Lime is consumed in the production of alumina for causticizing the sodium carbonate in extract liquors, and limestone is used to form dicalcium silicate in the sinter step of the combination process. For causticizing, an average of 175 pounds of lime was used to produce 1 ton of alumina, or 330 pounds per ton of primary metal. In the combination process the limestone consumption is a function of the silica content of the treated bauxite. Between 2.0 and 2.2 moles of lime is required for each mole of silica in the sinter amounting to 10 to 11 weight units of limestone for each 3 unit weights of silica. For bauxite containing 13 percent silica, calculated limestone requirements are equal in weight to the alumina product. Actual limestone requirements were less than the calculated amounts because a part of the silica was removed along with the heavy minerals in gravity separators after the Bayer extraction and before sinter preparation. The projected capacity of combination process plants was 1-1/4 million tons of alumina per year.

Other requirements, fuel, filter cloth, starch, and labor, are of interest because of the difference in requirements among the three types of plants. Available information shows the fuel requirements are 2-1/2 to 3 times greater for the combination process than for the Bayer processes; labor requirements double. Filter-cloth requirements are about 10 percent greater. Starch requirements are reported to be much higher for treatment of Jamaican ores.

Original from THE OHIO STATE UNIVERSITY

THE REDUCTION PROCESS

The major material requirements for reduction of alumina to metal are alumina, power, carbon, and flux or electrolyte materials. All of the alumina and carbon anodes consumed were produced by the industry, as were a large proportion of the electrolyte salts.

In the reduction, alumina is electrically disassociated into metallic aluminum and oxygen in a carbon-lined furnace or cell filled with molten fluoride salts in which the alumina is dissolved. The carbon lining acts as the cathode, and the anodes are suspended in the molten flux. The oxygen from the disassociated alumina unites with the carbon anodes to form carbon oxides. Metal is tapped from the bottom of the cell.

Alumina

In producing 1 ton of aluminum, 1.9 tons of alumina was consumed. As the industry was organized in 1952, all of the alumina consumed at reduction plants was produced by the consuming or an affiliated company. Anaconda was constructing a reduction plant without comparable alumina-producing facilities. Alumina was to be supplied by one of the established producers.

Power

The electrical energy consumed in the production of aluminum is generally quoted at 10 kw.-hr. per pound of metal. This requirement may be about right when all of the electrical requirements from mining, through alumina extraction to production of virgin metal are accounted for, however, the power consumed at reduction plants averaged approximately 8.5 kw.-hr. per pound of aluminum.

In terms of load factor there is probably no more efficient consumer of power than the alumina reduction process. The plants must operate 24 hours a day 7 days a week, and generating facilities may be utilized at almost 100 percent capacity. No peaking periods that require standby capacity are encountered as is usual among most other consumers. It is also true that the industry requires steady dependable power. Power failures result in furnace "freeze up" if not anticipated. In any case shutdowns are expensive in labor and material. The furnaces must be emptied, life of cell linings is shortened, and after power is restored several weeks elapse before normal production is obtained. Thus short term intermittent power supply cannot be used. However, power that is seasonal with long periods of supply and shutdowns was used for aluminum production.

To produce 1.7 million tons of aluminum, 29 billion kw.-hr. of power would be required. This is equal to the total power production of the Northwest power pool in 1950 and requires 3.3 million kilowatts of generating capacity equivalent to 4 percent of the United States generating capacity. Power was one of the major cost items in aluminum production, and a supply of large quantities of steady dependable low cost power has long been a major problem of the aluminum industry. The rapidly increasing demands of other industries, of public utilities and consumers that can afford higher power rates aggravated this

Original from THE OHIO STATE UNIVERSITY

problem. Each mill per kilowatt-hour increase in power costs represented an aluminum production cost increase of just under 1 cent per pound.

TABLE 3. - Raw material requirements[1] per ton of virgin aluminum

Alumina	lbs.	3,825
Power	kw.-hr.	17,000
Carbon (total)	lbs.	1,385
Green petroleum coke	do.	250
Calcined petroleum coke	do.	780
Pitch, high softening temp. (105°-115°C.)	do.	180
Pitch, low softening temp. (40°-70°C.)	do.	125
Coke or calcined anthracite	do.	50
Electrolyte, equivalent F_2 weight	do.	65
Cryolite	do.	47
Aluminum fluoride	do.	58
CaF_2 equivalent[2]	do.	148
H_2SO_4 equivalent[3]	do.	203
Labor	man-hours	26

1/ Based on industry average in 1951.
2/ Cryolite x 1.23 + AlF_3 x 1.55.
3/ CaF_2 x 1.37.

The average cost of power consumed for alumina reduction before the expansion was slightly over 2 mills per kw.-hr. Power costs at new installations were known to be higher, running 3-4 mills per kw.-hr. During the emergency beginning in 1950, the Government subsidized power costs above 5 mills per kw.-hr.

The selection of locations for reduction plants has been governed largely by the availability of low-cost power. One theory is that aluminum production, to remain competitive, must be carried out on the outer fringes of industrialized areas or in nonindustrial areas where competition from other consumers is at a minimum or virtually nonexistant and where large hydro or other low-cost power generating potentials are available. Such locations are fast disappearing in the Continental United States. During the pre-World War II period of the aluminum industry, reduction plants were located near large hydroelectric resources, first at Niagara Falls then in the Tennessee Valley and on the St. Lawrence. On completion of the large public dams of the Pacific Northwest, the aluminum-reduction industry expanded into this area, and in 1949, over 50 percent of the domestic production came from Washinton and Oregon. During World War II, when the supply of aluminum for war materials was critical and production costs were not a governing factor, the Government constructed a number of plants based on the use of thermally generated power. After the war only one of these plants survived peacetime competition. The generation system at this plant, at Jones Mills, Ark., was based on power produced from natural gas and diesel oil and marked a new trend in power for aluminum. Of the 667,000 tons of new reduction capacity completed or under construction as a result of the 1950-51 expansion program, 68 percent was to utilize power produced by thermal generation. All but one of the plants planned for use of thermal power was to use natural gas as the energy source. However, before the location of all of these plants had been definitely established, long-term, gas-supply contracts at attractive prices were difficult, if not impossible, to obtain, and the use of this material as a source of additional electrical energy for aluminum reduction was not promising. The one thermal plant not using natural gas was to employ lignite, a low-grade, subbituminous coal, and this installation in Milam County, Tex., may mark the beginning of a new trend in power production for alumina reduction. Large unexploited deposits of low-grade coals are located in a number of relatively nonindustrialized areas of the United States, and the demonstration of the economic use of materials of this type would be a boon to the aluminum industry.

The above is not to say that hydroelectric power for aluminum production will be replaced. New plants that will use hydroelectric power are located at Wenatchee, Wash., and Columbia Falls, Mont. Power was to be supplied from the Rock Island and Hungry Horse Dams. The capacity of established plants in the Pacific Northwest was enlarged.

An alternative to the use of domestic power was establishment of reduction facilities outside of the continental United States. Alaska has been investigated by primary aluminum producers as a promising location. South American countries, Venezuela, Brazil, and the Guianas have also been considered.

As shown above, it will become increasingly difficult and probably more expensive to secure an adequate power supply, but to maintain the price relationships of aluminum with other metals, low-cost power or a means for reducing power requirements is a necessity.

Carbon

Most of the carbon used in aluminum production is consumed as anodes at the electrolytic cell. These anodes must be of high purity because ash from the electrode enters the electrolyte and contaminates the electrolyte and the metal. Carbon is also required for the cathode or cell lining, which deteriorates and periodic replacement is necessary. The frequency of relining varies from plant to plant and from cell to cell, depending on the quality of the lining, operating conditions, and frequency of shutdowns. The life of a cell lining is generally 2 or 3 years. In relation to anode consumption the requirements for cathode carbon are small.

Petroleum coke is used in the production of anodes, which are either prebaked or self-baking Soderberg electrodes. Both green and calcined petroleum coke are used; the proportional requirements for each type vary among the three producers and even between plants of the same producer, depending on the type of electrodes used and on electrode production practices. For Soderberg electrodes calcined coke is used almost exclusively. On an industry basis the ratio of calcined to green coke consumption is approximately 3:1. In addition to petroleum coke, pitch of various softening temperatures from 40° to 115° C. is used as a binder in electrode production. Total pitch requirements are about one-third those of coke. Most of the cathode carbon is supplied as beehive coke or calcined anthracite. The cell lining material does not need to be

Original from THE OHIO STATE UNIVERSITY

as pure (ash free) as the anode carbon but requires greater structural strength. Impurities are leached from the cell lining during the initial period of operation by molten electrolyte. The first metal produced is not, of course, of standard purity but could be used to prepare alloys containing the metals that are leached from the linings. For each ton of aluminum produced, average material requirements are 780 pounds of calcined coke, 250 pounds of green petroleum coke, 180 pounds of pitch with a high softening temperature (105° $\frac{1}{N}$ 115° C.), 125 pounds of pitch with low softening temperatures (40°$\frac{1}{N}$70° C.), and 50 to 60 pounds of beehive coke and/or calcine anthracite.

The excess requirements of low-ash carbon required for new facilities are, like soda ash in the alumina plants, small in relation to consumption. Petroleum coke, beehive coke and calcined anthracite, and pitch are required for constructing pot linings and for setting up the electrode plants. Available data show that the startup requirements are much greater for plants using Soderberg electrodes than for those using baked carbon electrodes, averaging 400 pounds for Soderberg plants and 120 pounds for baked electrode plants per ton of new production capacity.

Carbon requirements for the aluminum industry were about 65 percent of the metal production. Most of this carbon is required in the form of petroleum coke, and in 1951 a survey of petroleum coke suppliers indicated that supplies would be adequate. Petroleum industry representatives have also indicated that coke production could be increased by making minor changes in petroleum refining practices.

Electrolyte or flux

The basic electrolyte or flux material is cryolite, Na_3AlF_6. However, the determination of raw materials required for electrolytes is complex because of the substitution of synthetic for naturally occurring cryolite and the use of AlF_3 as a partial replacement. As the molten flux disassociates and is consumed in the reduction process, various salts are added to the bath to keep it at a uniform composition and density. Cryolite is supplied as a naturally occurring mineral and as a synthetic product, which was produced by reacting HF with sodium aluminate liquors. Aluminum fluoride is produced by reacting HF with hydrated alumina. Soda ash and alumina consumption in flux is not significant when compared to other requirements for these materials, and the major additional element entering the production cycle is fluorine. Flux consumption is conveniently expressed in units of fluorine per unit of product and averaged 0.033 unit weights of fluorine per unit weight of aluminum production. This is equivalent to 130 pounds of cryolite (98 percent Na_3AlF_6). In practice, variable amounts of cryolite and AlF_3, are used and consumption ratio in 1951 was 4 parts of cryolite to 5 parts of aluminum fluoride.

The only known commercial deposit of cryolite was located in Greenland, and the remaining life of that deposit has been reported as 10 to 15 years. Mine-production sales were controlled by the Danish Government. In 1951, 34,688 long tons of crude ore was imported, from which a little more than 20,000 tons of refined cryolite was supplied to the aluminum industry. Imports have shown wide fluctuations during the past 10 years, from a high of 64,565 long tons of crude ore in 1942 to a low of 2,101 long tons in 1948, and it is probable that eventually all fluorine requirements will be obtained from other sources.

All of the fluorine not obtained from cryolite consumed by the aluminum industry comes from acid-grade fluorspar, and, if this material were to supply the total fluorine requirements, 140 to 145 pounds would be required for each ton of aluminum production. To produce 1.7 million tons of aluminum, 120,000 tons of acid grade spar, about equal to total 1951 production, and 165,000 tons of H_2SO_4 would be required. Fluorspar requirements are not this high as flux can and is being recovered from spent pot linings. The Aluminum Company of America has been treating pot linings since 1951, and the other producers installed recovery facilities during 1952. After the treatment of the backlog of accumulated linings, 7,000 to 8,000 tons per year are anticipated from this source. There is also a good possibility that byproduct fluorine from other materials, for example, phosphate ores might be used. Fluorine consumption may be reduced by improved operation techniques, such as more efficient recovery of fluorine from cell fumes and rakings.

In addition to the cryolite consumed in production, large quantities are required for starting new reduction plants. Cryolite is required to fill the cells and additional quantities are absorbed by the cell linings during the first few months of operation. The quantity required varies with the cell design and the type of lining. Cells using Soderberg-type anodes have starting requirements more than double those equipped with prebaked anodes. Most of the new reduction capacity installed under the 1950-52 expansion program was to be of the Soderberg type, and cryolite requirements for starting were estimated at 140 pounds per annual ton of new capacity for starting up the plants and an additional 175 pounds absorbed by the cell lining. All of the above cryolite requirements are expressed in terms of natural refined cryolite (98.5 percent Na_3AlF_6) and must be increased by 7 percent when synthetic cryolite is used. During the expansion period, 1950-55, the 850,000 annual tons of new capacity programed will require 134,000 tons of cryolite above normal process requirements.

The cryolite supply problem was basically one of creating adequate production capacity for synthetic fluorides. This problem was aggravated by an expansion program, such as that in progress, where production capacity necessary to supply the one time requirements of new plants would not be required for operating consumption. The annual fluorspar consumption capacity of synthetic flux plants was about 83,000 tons at the end of 1951. The indicated fluorspar consumption for the 5-year expansion period, assuming natural and reclaimed cryolite totaling 70,000 tons, was 600,000 tons of CaF_2, an average of 120,000 tons per year. The Government encouraged construction of synthetic flux plants through accelerated amortization and guaranteed purchase contracts, and synthetic flux production capacity was expanded. At the end of 1952, adequate capacity was not available based on the above supply pattern. Either additional synthetic flux plants or a high rate of imports of natural cryolite were required to meet the expansion schedule. Sulfuric acid requirements will be almost 1.4 times those of fluorspar. Recent and programed increases in acid-grade fluorspar and sulfuric acid production indicated that these materials would be available.

Labor

The labor requirements for aluminum production are somewhat unique because of the high power consumption per man-hour of electrical power consumption. A study of the labor force compared to power consumption in the Northwest area showed that aluminum reduction consumed 58 percent of the electrical energy and employed approximately 2 percent of the labor force. This accentuates the power-supply problem, especially during periods of temporary power shortage when reductions in aluminum production will have minimum affects on the labor market and militates against the expansion or initiation of production in areas where large labor forces are available.

The raw material requirements of the 1952 expansion program have been provided for, with the possible exception of flux materials. Power shortages caused by low water conditions in the Pacific Northwest, Tennessee Valley, and St. Lawrence areas occurred seasonally and prevented capacity production at plants located in these areas. Reliance upon imported bauxite was increasing and the increased demands for petroleum coke and fluoride fluxes necessitated the construction of additional processing capacity. A look into the future indicates that ever-increasing quantities of aluminum will be consumed in the United States and the rest of the world for some time to come. Unless some new process requiring other raw materials is developed the drain on domestic and world reserves of the above raw materials will continue to increase.